Learning to Think Inductively

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"Thinking inductively is inborn and lawful. This (school renewal) is revolutionary work, because schools have decided to teach in a lawless fashion, subverting inborn capacity."

~Hilda Taba to a group sitting on the steps of the Lincoln Memorial

Learning to process information inductively has a vital place in teaching students how to learn better. And no area illustrates better the oxymoronic character of helping students to learn. As Taba said, so many years ago, babies are born with the capacity to classify and they begin to use it right away. Within a few months we can see their learning in two ways. One is in the development of categories about their immediate environment, and the second is in language development.

Very soon they can distinguish the cat from a stuffed animal and things that float in the bath from things that sink.

Not long after, these young people are recognizing words and trying to use them. By age three or so, they have learned an astonishing number of categories of words. In primitive speech, they will put the subject before the word and inflect the end of a question.

We want to unfetter their cognitive birthright – in a sense to get out of the way of the inborn capacity. Also, however, and this is important, we want to help our young to enhance their skills – to become more and more self-consciously capable. And, that does not happen automatically.

Curiously, the classification skill that serves so well during the first four or five years can be arrested in the school years as the child tries to imitate adult learning rather than continuing the process of inventing concepts and skills that dominates the delightful infant and early childhood years. And, through inquiry, we have refined ways of classifying and can help the students explore them and enhance their learning during the later childhood, pre-adolescent, adolescent, and young adulthood years. As Taba indicated, there are curriculums and ways of teaching that actually subvert and can even derail, this major part of humanness. Available, also, are versions of the inductive model of learning – ways of helping our children enhance their tools for building and using categories. In these pages, we will concentrate on one of them – one that has been researched and polished to make it viable.

Let's begin with a simple example.

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SCENARIO 1: The Seamus Inquiry

Eight-year-old Seamus is apparently playing in his kitchen. In front of him are a number of plates. On one is a potato, cut in quarters. Another contains an apple,

similarly cut. The others contain a variety of fruits and vegetables. Seamus pushes into the segments of potato a number of copper and zinc plates which are wired together and to a tiny light bulb. He nods with satisfaction when the bulb begins to glow. He disconnects the bulb, attaches a voltmeter, examines it briefly and then reattaches the bulb. He repeats the process with the apple, examining the bulb and voltmeter once again. Then come the raspberries, lemon, carrot and so on. His father enters the room and Seamus looks up. 'I was right about the raspberries,' he says, 'we can use them as in a battery. But some of these other things . . .'

Seamus is, of course, classifying fruits and vegetables in terms of whether they can interact with metals to produce electric current.

Reflection: The Seamus Inquiry

Before this inquiry was initiated, Seamus has had a good deal of experience with the classification process. He's classified the characteristics of animals and their habitats (see later). He has classified words and sentences and the titles of books. In fact, the last is what led to the inquiry with fruits, vegetables, and batteries after he found a little book on the basics of electricity. With the help of his parents, he set up a study of metals that would and would not become electromagnets when surrounded with a coil. And, then they found a kit with tiny lights and voltmeters and the copper and zinc plates, and he began to classify the groceries according to whether and how much they generated electricity.

This little scenario illustrates how direct are the components of classification:

We need a set of data relative to some content domain.

We need to examine the items in the set, noting their attributes. To do so thoroughly, we may need to operate on the data set (in this case collecting the further information about the production of electricity. And, we may need a measurement device (such as the little light and the voltmeter).

And, we need to make notes of some kind or, possibly, here, make piles of the groceries depending on the results.

Then, reflecting on what is learned leads to a clarification of the concepts and, importantly, the development of names for them. What shall we call the fruit that generates the most electricity? Will dictionary or encyclopedia help us – or other non-fiction books on electricity?

As we continue to explore the learning process, note that, although this illustration focuses on a single child, a classroom or laboratory can be set up so that larger numbers of students can carry on the same type of inquiry that Seamus did. We will proceed to a first grade class on the first day of school where the schooling process begins with classification with no need for special equipment.

SCENARIO 2: The Diane Inquiry

Diane Schuetz provided each of her first grade children with sets of tulip – each had a dozen or so on their desks. She asked them to examine the bulbs carefully. Then she asked them to make categories (move the bulbs around into groups, putting similar ones together).

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Gradually, the students formed groups according to characteristics like size (putting big and little ones together), whether were joined together ('Some have babies on them said some of the children'), whether they had 'coats,' or whether they had the beginnings of what look like roots.

Diane led the children to share their ideas, moving around their set as the others shared (as putting those with "babies" or "coats" in a temporary pile).

Diane had set up a number of boxes, half of which were filled with potting soil and the other half with water. Above the boxes she arrayed ultra-violet lights.

She then organized the children to plant half of their bulbs and place the other half in stones in the water. As they planted them, she made cards with their hypotheses written on them, such as

'Will the big ones [bulbs] grow bigger?' 'Will the babies grow on their own?' 'Will the ones in soil do better?' and so on. She has designed the science curriculum area around the basic processes of building categories, making predictions and testing them.

Reflection – Diane Inquiry

Again we can see the essentials of learning to develop and use categories. Repeating ourselves somewhat:

We need a set of data relative to some content domain. In this case, the bulbs make up the data set, and the domain is growth from bulb to plant.

We need to examine the items in the set, noting their attributes. Here, the students can use their eyes and hands to take in the attributes.

And, we need to make notes of some kind or, as here, make piles of the bulbs as classification proceeds.

Then, reflecting on what is learned leads to a clarification of the concepts and the development of questions – hypotheses by these young people.

Given that this is the first day of school for these children, you can imagine that thinking will be the theme of the curriculum. Diane will use other models of learning, as we will see later, but she is unafraid to lead her students to explore their content with their good heads. By the way, how many first grades have the depth and relevance hers is going to develop. And, as they make their observations and dictate them to her, can we expect that a healthy part of the literacy (reading and writing) curriculum will develop over inquiries into content.

SCENARIO 3: Biology in India with Bharati Baveja

At the Motilal Nehru School of Sports in the state of Haryana, India, two groups of 15-year-olds are engaged in the study of a botany unit that focuses on the structure of plant life. One group is studying the textbook with the tutorial help of their instructor, who illustrates the structures with plants found in the grounds of the school. We will call this group the presentation/illustration group. The other group, which we will call the inductive group, is taught by Dr. Bharati Baveja, an

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instructor at Delhi University. This group is presented with a large number of labeled plants. Working in pairs, Bharati's students build classifications of the plants based on the structural characteristics of their roots, stems and leaves. Periodically, the pairs share their classifications and generate labels for them.

Occasionally, she employs concept attainment to introduce a concept designed to expand the students' frame of reference and induce more complex classification. She also supplies the scientific names for the categories the students invent. Eventually, Bharati presents the students with some new specimens and asks them to see if they can predict the structure of one part of the plant from the observation of another part (as predicting the root structure from the observation of the leaves). Finally, she asks them to collect some more specimens and fit them to the categories they have developed so they can determine how comprehensive their categories have become. They discover that most of the new plants will fit into existing categories but that new categories have to be invented to hold some of them.

Reflections on the Baveja Experience

After two weeks of study, the two groups take a test over the content of the unit and are asked to analyze more specimens and name their structural characteristics.

The inductive group has gained twice as much on the test of knowledge and can correctly identify the structure of eight times more specimens than the presentation/illustration group. Inductive teaching and learning has a strong base of research that fits with the Baveja results.

SCENARIO 4: Classifying with Sharon Champ

We now take the reader into an exploration of a data set generated by a wonderful teacher for her students in the Saskatoon, Saskatchewan, public schools. Rather than describe how she led her students, we invite the reader to examine the data set and form concepts. Sharon Champ is a literacy trainer in the Saskatoon Public School District. She decided to build a set where several concepts about syntactic structures of sentences are built in so that they might be discovered as the students build their categories. The content objective is to increase the students' study of sentences and how they are structured to convey particular types of meanings. Let's look at the structural characteristics of twenty-one of the sentences.

In the grass, the spider patiently weaves her web.

In the trees, birds gather to eat berries.

In the forest, a squirrel leaps from tree to tree.

In the space shuttle, the astronauts complete their experiment.

In the burrow, the rabbit family nestles together to keep warm.

In the cockpit, the pilot carefully checks his instrument panel.

In the icy water, a penguin dives and splashes.

Under the sea, large sharks circle the school of fish.

Near the trees, lion cubs scamper in the tall grass.

Under the water, the diver silently searches for a dolphin.

Under the snow, a hungry mouse burrows deep looking for food.

Beside the school, two small boys play catch with a bright red ball.

Behind the mountain tops, dark storm clouds are gathering.

Between the trees, a small monkey wrestles with its mother.

Beside the river, a bear cub scrambles on the rocks.

Between the rocks, a snake slithers to search for food.

On the surface of the pond, a loon floats peacefully.

Hidden under leaves, a spotted frog hides from the sun's brilliant rays.

Deep in the forest, a black panther patiently waits to pounce on her prey.

High in the sky, the lone eagle glides gracefully.

Far below the earth's surface, molten lava rumbles and boils.

From a formal perspective, each of these sentences contains a prepositional phrase that provides information about WHERE the action takes place.

Sharon reasons that if the students can build a category that contains those attributes (prepositional phrases and their attributes and the meaningful content, "WHERE") they can use the category as they read, looking for structures that provide particular meanings, and as they write, building a tool for giving their readers information about, in this case, WHERE.

So, the rest of the set does not contain prepositional phrases that tell us where:

Penguins have huge appetites.

This bird is a rockhopper penguin.

You would not want to fight a grizzly bear!

Clouds come in all shapes and sizes.

A blue whale is not a fish.

This tough bird is an emperor penguin.

The small dog yapped impatiently.

In the day, bats sleep upside down.

At twilight, bat's sharp cries fill the air.

At night, the owl hunts silently for mice and rabbits.

In the winter, most bear hibernate.

Frogs lay eggs.

A duck makes its nest carefully.

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The young penguin wants to be close to its mother..

A woman and her children are standing up now.

The woodpecker searches for insects.

The woodpecker is building a nest.

These last sentences are mixed with the first 21 as Sharon presents the set to her sixth grade students. She asks them to look at characteristics of the sentences and the kinds of information that is conveyed. She asks them not to focus on specific bits of information (as where the yak lives) but on general information conveyed by a particular characteristic of the sentences.

Clearly, this is not the first lesson on sentence structure and purpose, but part of a long unit dealing with comprehension in reading and ways of conveying information in writing.

What do you think? What categories do you suppose the students formed in their inquiry?

THE CLASSIFICATION CORE: INDUCTIVE THINKING AS A MODEL OF LEARNING

The scenarios that introduce this section illustrate the inductive model in operation. The inductive model has a long history. Inductive thinking has been written about since the classical Greek period, and the model has been polished and studied formally during the last 30 years. Very important to current classroom use was the work of Hilda Taba (1966, 1967), who was largely responsible for popularizing the term teaching strategy and for shaping the inductive model so that it could be conveniently used to design curricula and lessons. See also Joyce and Calhoun (1998).

The inductive model causes students to collect information and examine it closely, to organize it into concepts and to learn to manipulate those concepts. Used regularly, this strategy increases students' abilities to form concepts efficiently and increases the range of perspectives from which they can view information.

If a group of students regularly engage in inductive activity, the group can be taught to use a wider range of sources of data. The students can learn to examine data from many sides and to scrutinize all aspects of objects and events. For example, imagine students studying communities. We can expect that at first their data will be superficial, but their increasingly sophisticated inquiry will turn up more and more attributes that they can use for classifying the information they are gathering. Also, if a classroom of students works in groups to form concepts and data, and then the groups share the categories they develop, they will stimulate each other to look at the information from different perspectives.

PHASES OF THE MODEL

Think about the scenarios at the beginning of the chapter as you review the phases of the inductive model of teaching and learning. The flow of the inductive process is made up of several types of inquiry that overlap considerably:

- identifying an area of study – a domain that contains conceptual or actual

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territory to be explored;

- collecting and sifting information relevant to that area or domain of inquiry; sometimes the students create the data set, sometimes it is the instructor.
- constructing ideas, particularly categories, that provide conceptual control over territories of information;
- generating hypotheses to be explored in an effort to understand relationships within that domain or to provide solutions to problems;
- testing hypotheses, including the conversion of knowledge into skills that have practical application; and
- applying concepts and skills, practicing them and developing 'executive control' over them so that they are available for use.

In this flow of cognitive operations, we find the definition of induction, for in these types of inquiry, the student constructs knowledge and then tests that knowledge through experience and against the knowledge of experts. Induction, rooted in the analysis of information, is often contrasted with deduction, where one builds knowledge by starting with ideas and proceedings to infer further ideas by logical reasoning.

Although it is convenient to imagine a prototype inquiry that begins with data collection and organization and proceeds to the development of categories, the generation and testing of hypotheses and perhaps then to the development of skills, the inductive process may begin at any of these stages or phases. Now, consider how the inductive process emerges.

COVERAGE AND CONCEPTUALIZATION

Although much research on information processing models has been focused on how to increase students' ability to form and use concepts and hypotheses, a number of questions asked by both practitioners and laymen are particularly relevant here. The questions mainly reflect the concern we have mentioned earlier—that a concentration on thinking might inhibit the mastery of content.

Teachers put the question something like this: "I have much content to cover. If I devote energy to the teaching of thinking, won't the students miss out on the basic skills and content that are the 'core' of the curriculum?"

Several reviews of research have addressed this question. El-Nemr (1979) concentrated on the teaching of biology as inquiry in high schools and colleges. He looked at the effects on student achievement, on the development of process skills and on attitudes toward science. The experimentally oriented biology curricula achieved positive effects on all three outcomes. Bredderman's (1983) analysis included a broader range of science programs and included the elementary grades. He also reported positive effects for information acquisition, creativity, science process and, in addition, on intelligence tests where they were included. Hillocks' (1987) review of the teaching of writing produced similar results. In short, the inductive inquiry-oriented approaches to the teaching of writing produced average effect sizes of about 0.60 compared to treatments that covered the same material, but without the inductive approaches to the teaching/learning process.

Some other researchers have approached the question of 'coverage' in terms of

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the transfer of the teaching of thinking from one curriculum to another and found that inquiry-oriented curricula appear to stimulate growth in other, apparently unconnected, areas. For example, Smith's (1980) analysis of aesthetics curricula shows that the implementation of the arts-oriented curricula was accompanied by gains in the basic skills areas.

The question of time and efficiency has been addressed recently in a number of large-scale field studies in the basic curriculum areas. An example has been provided by the 190 elementary school teachers of an Iowa school district. The teachers and administrators in this district focused on improving the quality of writing of their students by using the inductive model of teaching to help students explore the techniques used by published authors to accomplish such tasks as introducing characters, establishing settings and describing action. At intervals, teachers collected samples of the children's writing, and those samples were scored by experts who did not know the identity of the children.

By the end of the year, student writing had improved dramatically. In the fourth grade for example, their end-of-year scores for writing quality were higher than the end-of-year scores for eighth grade students the previous year! Students had made greater gains in one year than were normally achieved by comparable students over a period of four years. Moreover, students at all levels of writing quality had gained substantially – from the ones who started with the poorest writing skills to the ones who began with the most developed skills. The 'gender gap' in writing (males often lag behind females in developing writing skills) narrowed significantly (Joyce et al. 1994, 1996).

That the same type of curriculum reached all the categories of students is surprising to many people, but it is a typical finding in studies of teaching and teaching strategies. Teachers who reach the students with poor histories of learning and help them out of their rut also propel the best students into higher states of growth than they have been accustomed to.

We stress that students are natural conceptualizers. Humans conceptualize all the time, comparing and contrasting objects, events, emotions—everything. To capitalize on this natural tendency, we arrange the learning environment and give tasks to students to increase their effectiveness in forming and using concepts, and we help them consciously develop their skills for doing so. Over the years we have generated guidelines for shaping the environment and creating tasks that facilitate concept formation. As students become more skilled in inductive learning, we modulate our behavior, helping them create appropriate environments and tasks. Learning how to think inductively is the critical goal, and the students need to practice it, not just be led through it. The guidelines for shaping the environment (designing lessons and units) are straightforward.

One is focus—helping the students concentrate on a domain (an area of inquiry) they can master, without constricting them so much that they can't use their full abilities to generate ideas. At first, we do this by presenting the students with data sets that provide information in the domain that will be the focus of the lesson or unit and by asking them to study the attributes of the items in the set. A simple example is to present kindergarten or first grade students with cards containing several letters from the alphabet and ask them to examine them closely and describe their attributes. The domain is the alphabet: letters and their names. Another example is to present fifth or sixth grade students with a data set containing statistical data on the countries from a region of the world, say, Latin

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America, and ask the students to study the data on each country carefully. The domain is Latin American countries, with the subdomain of statistical data.

Second is conceptual control—helping the students develop conceptual mastery of the domain. In the case of the alphabet, the goal is to distinguish the letters from one another, and to develop categories by grouping letters that have many, but not all, attributes in common. The students will learn to see the alphabet in terms of similarities and differences. They will also find those letters in words and, when they have made categories of letters with the same shape (as putting a half-dozen b's together), will learn the names of those letters as we supply them. The letters will be placed on charts in the classroom along with words that contain them. In the case of the Latin American countries, the students will classify the countries according to the demographic data provided in the set, moving from single-attribute categories such as population and per capita income to -multiple-attribute categories such as determining whether variables like education levels, fertility, and income are related. They will be able to see Latin America in terms of those categories, a step toward the conceptual control that will emerge as they add more data to their set and develop advanced categories, gaining meta-control by developing hierarchies of concepts to gain further mastery of the domain.

The third guideline is converting conceptual understanding to skill. In the case of the alphabet, this is exploring letter–sound relationships and how to use them in reading and spelling, where recognition evolves to conscious application in word identification. In the case of the Latin American countries, the skills are in the development of multiple-attribute categories and generating and testing hypotheses (such as studying whether per capita income is related to fertility rates or education levels).

The environment is made up of the development of the learning community, the creation of the data sets, and the learning tasks—classification, reclassification, and development of hypotheses. Also, the teacher observes the students and scaffolds their inquiry by helping them elaborate and extend their concepts. In the alphabet example, tasks like "which letters are most like the 'a' and are most likely to be confused with it" would be generated. In the Latin American example, tasks like "what other variables might be correlated with levels of literacy" would be generated.

As the students learn to build and extend categories (concepts), they take on increased responsibility for the process. For example, they learn to build data sets that are relevant to the domains being studied. Our kindergarten/first grade students use their word charts to develop data sets, at first with explicit guidance ("Here are three words that begin the same. Can you add to my list?") and later by looking at the list and sorting the words independently according to how they begin and end. Our young scholars on Latin America learn to add variables to the data base using statistical sources and expository sources like encyclopedias. As their study of nations proceeds, they will be able to create data sets on regions and sets that enable them to compare and contrast entire regions.

The inductive model leads students to collect information and examine it closely, to organize the information into concepts, and to learn to manipulate those concepts. Used regularly, this strategy increases students' abilities to form concepts efficiently and increases the range of perspectives from which they can view information.

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